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HARD-BUBBLE-FREE EPITAXIAL GARNET FILMS: THE GARNET-PERMALLOY COMPOSITE STRUCTURE

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Epitaxial garnet films have presently been considered to be the most suitable medium for magnetic bubble devices. However, the coexistence of extraordinary bubbles or "hard" bubbles with normal ones in garnet films, which has recently been observed[1], may be fatal to the application of garnet films to device use. Hard bubbles are very disruptive to the operation of bubble circuits since they not only have a lower velocity than normal bubbles, but also move at an angle to the direction of a driving field gradient. The difference between normal and hard bubbles results from the domain wall structures. The theories based on the domain wall structure where the wall of hard bubbles consists of alternate Bloch and Néel segments have been able to well explain these anomalous phenomena and other properties of hard bubbles.

It is, therefore, urgent to develop a method to suppress hard bubbles. Two methods have successfully eliminated hard bubbles: Ion implantation[3] and multiplication of epitaxial garnet layers[4]. Both methods involve providing a second magnetic layer interacting with the bubble-supporting layer at the interface, resulting in making it energetically unfavorable for a bubble wall to take such a complex structure as hard bubbles. It is suggested that a second magnetic layer, having a large exchange constant and exchange-coupling with the bubble supporting layer at the interface, is essential to suppress hard bubbles.

The present work demonstrates that Permalloy thin films down to 50Å in thickness evaporated on garnet epitaxial films can eliminate hard bubbles. Also, it is shown by measurements of wall velocities and bias field margins and bubble-sensing experiments that the Permalloy overlay is excellent in practical device use.

The garnet film used was liquid phase epitaxially grown $(Y,Gd,Tm)_3(Fe,Ga)_5O_{12}$; the material constants are tabulated on the inset of Fig. 1. The garnet film was cut to four specimens to deposite Permalloy films of four different thicknesses. 80Ni-20Fe Permalloy was vacuum-evaporated on the specimens. The typical conditions were the following: the deposition rate = 5.7Å/sec, the substrate temperature = 230°C, and the vacuum = 5.8 to 9.0 $\times 10^{-6}$ Torr.

Figure 1 shows H_o, H'_{os} and H'_{os}/H_o as a function of Permalloy thickness where H_o is the collapse field of a normal bubble and H'_{os} the maximum collapse field of hard bubbles. The collapse fields of hard bubbles are higher than H_o, which is the most characteristic static property of hard bubbles. The ratio, H'_{os}/H_o, can therefore stand for "hardness" of bubbles[1,5]; the ratio equal to 1 indicates the absence of hard bubbles in a film. The method used to produce hard or normal bubbles was similar to those previously reported[5,6], while it was noticed that a combination of the two methods was more effective to form hard bubbles. As seen in Fig. 1, the ratio of H'_{os} to H_o is unity for Permalloy with thickness of more than 50Å, indicating the absence of hard bubbles in these samples. The initial increase of H_o with Permalloy thickness is qualitatively understood in terms of a decrease of magnetostatic energy by overlaying a Permalloy film. Microscopic interpretaion of this hard bubble suppression is being undertaken, which will explain the behavior of H_o as well.

In the vicinity of $H'_{os}/H_o = 1$, wall velocity is a very sensitive measure of hardness since it sharply decreases as the ratio differs from unity$^{7)}$. Measurements of wall velocities showed that the Permalloy film itself did not cause any reduction in the wall velocity. Furthermore, the hard bubble suppression by evaporated Permalloy films was comfirmed by these measurements.

A bias field margin, $\frac{H_o - H_2}{(H_o + H_2)/2}$, was found to remain unchanged up to 200Å thick Permalloy being 0.26, but decreased to below 0.2 for 300 to 400Å. Here, H_2 is the runout field. Also, it was experimentally shown that output signals of InSb Hall effect detectors$^{8)}$ obtained for garnet films with 80 and 290Å thick Permalloy were as high as those for garnet films without Permalloy. Thus, this garnet-Permalloy composite structure is very promising for eliminating hard bubbles in actual device use, since the deposition of Permalloy is a fundamental process in the bubble technology.

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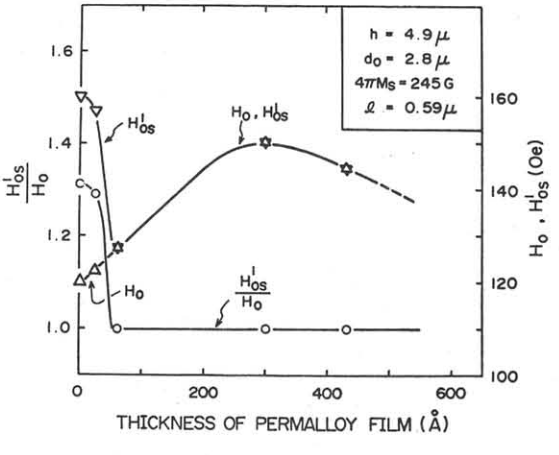

Figure 1. H_o, H'_{os}, and H'_{os}/H_o as a function of thickness of Permalloy film. Inset shows material constants of sample used. h is garnet film thickness, d_o collapse bubble diameter, $4\pi M_s$ saturation flux density, l characteristic length.